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Neutron Energy Spectra from Proton Bombardment of Thick Lithium Targets in the 50-180 MeV Energy Range

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It has been proposed to use surplus protons of the NAL 200 MeV Linac injector for cancer treatment.[1] From presently available sources, cancer therapists favor a broad neutron spectra centered from 8 to 22 MeV to irradiate tumors. Extensive use has been made e.g. of neutrons from deuteron bombardment of beryllium in the 15-50 MeV energy range. When the primary beam consists of protons, an attractive target material appears to be lithium. In addition to having low Z (which tends to yield a harder neutron spectrum), lithium has a low melting point (~200°C) and so would facilitate making a radiation resistant liquid target. While the choice of an optimum target (material, thickness, etc.) and incident proton beam (energy, size, etc.) is obviously a complex question, some preliminary estimates of neutron spectra are necessary to compare their biological effectiveness against those already in use elsewhere.

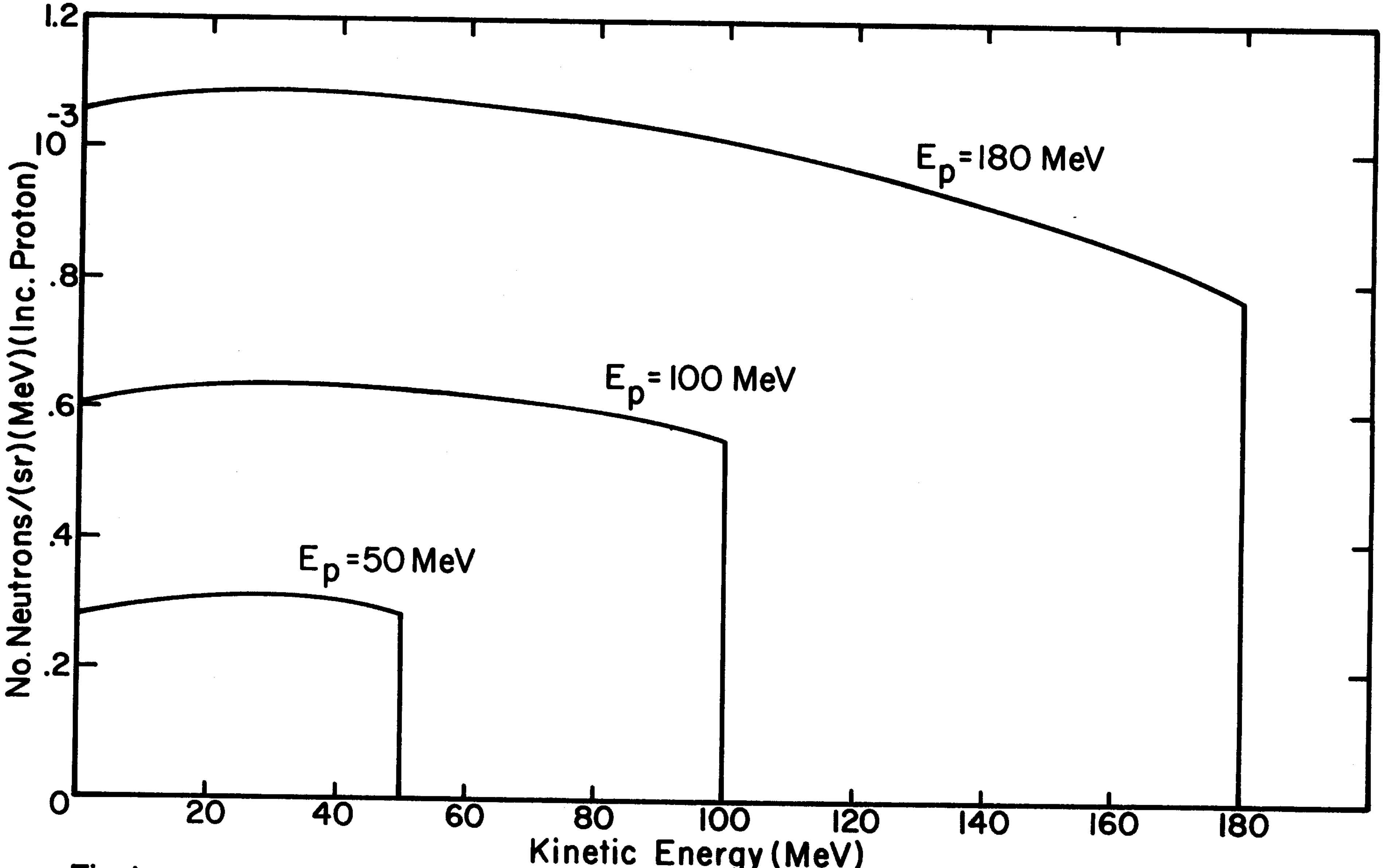
This note presents some calculated neutron spectra in the forward direction for 50, 100 and 180 MeV protons incident on a Li target which has a length equal to the range of the incident protons (5.0, 17.5, and 49. cm, respectively). A typical thin-target neutron spectrum exhibits a flat region extending over most of the energy range followed by a series of sharp peaks close to the incident energy.[2] The latter are associated with events where the residual Be^7 nucleus is left in the ground state or a low lying excited state. The flat region is associated with nuclear break-up. To facilitate the calculation the spectrum was represented by a uniform neutron distribution between zero and the incident energy with a delta function (idealizing the peaks) superimposed at the incident energy. The numerical values of the uniform distribution and the area under the peak were assumed to be smoothly varying functions of energy and were derived from experimental data. The effect of secondary interactions in the target was approximated by averaging the spectra calculated with neutron absorption included and neglected.

The resulting spectra are shown in Fig 1. The sharp cut-off at the incident proton energy reflects the simplifying assumptions introduced but this should not introduce serious error in calculating the biological effectiveness (dose) of the spectra.

References

1. A Possible NAL Medical Applications Facility, prepared by the NAL Medical Applications Committee (1973)

2. C. J. Batty et al, Rutherford Lab. preprint RPP/P 19 (undated); W. F. Goodell, Jr., et al., Phys. Rev. 89, 724 (1953); J.A. Hofmann and K. Strauch, Phys. Rev. 90, 449 (1953) P.H. Bowen et al., Nucl. Phys. 30, 475 (1962); C.J. Balty et al., Phys. Lett. 19, 35 (1965); C. J. Batty et al., Nucl. Phys. A 120, 297 (1968)



No. Neutrons/(sr)(MeV)(Inc. Proton)
10^{-3}
1.2
.8
.6
.4
.2
0
20
40
60
80
100
120
140
160
180
Kinetic Energy (MeV)
E_p = 180 MeV
E_p = 100 MeV
E_p = 50 MeV

Fig. 1